

DESCRIPTION

BRAKE CONTROL DEVICE FOR INDUSTRIAL VEHICLE

5 TECHNICAL FIELD

[0001] The present invention relates to a braking control device for an industrial vehicle.

10 BACKGROUND ART

[0002] In recent years, attempts have been made to configure industrial vehicles such as towing tractors or forklifts as electric vehicles capable of autonomously traveling in a limited area, for example. An industrial vehicle as above includes
15 a braking member that is formed of a traveling motor generating a regenerative braking force and a mechanical brake generating a mechanical braking force, so that braking is performed by regeneration obtained by the traveling motor during a travel on a downhill slope, for example, with autonomous driving.

20 [0003] As a braking control device for an industrial vehicle, a technique described in Patent Literature 1 is known, for example. The braking control device for the industrial vehicle described in Patent Literature 1 controls an inverter control device so as to limit a regenerative torque command value of a traveling motor based on terminal voltage of a battery in which the regenerative electric power
25 obtained by the traveling motor is charged.

Citation List

Patent Literature

30 [0004] Patent Literature 1: Japanese Patent Application Publication No. 2012-200048

SUMMARY OF INVENTION

Technical Problem

[0005] In an industrial vehicle configured as an electric vehicle capable of autonomously traveling as described above, there may be cases where a regenerative braking force is not obtained for protection of the battery when the battery is in a fully charged state, due to an influence of a downhill slope. However, a traveling plan is not necessarily generated in advance in consideration of the influence of the downhill slope existing in a traveling route during the autonomous driving. Thus, when the industrial vehicle autonomously travels in the traveling route including the downhill slope while the battery is in the fully charged state, there may be a case where the regenerative braking force is not obtained to fail to realize a desired requested braking force. Meanwhile, an operating time of the industrial vehicle may become shorter when a charging amount of the battery is pre-limited so as to allow the battery to be charged by regeneration.

[0006] An object of the present invention is to provide a braking control device for an industrial vehicle capable of suitably performing braking even when the industrial vehicle travels downhill with a battery being in a fully charged state, without necessarily generating a traveling plan in advance in consideration of an influence of the downhill slope.

Solution to Problem

[0007] In a braking control device for an industrial vehicle according to one aspect of the present invention, the industrial vehicle including a braking member that is formed of a traveling motor generating a regenerative braking force and a mechanical brake generating a mechanical braking force. A battery is charged using the regenerative braking force. The braking control device includes: a map information acquisition unit configured to acquire map information; a position information acquisition unit configured to acquire position information of the

industrial vehicle; a traveling information acquisition unit configured to acquire traveling information of the industrial vehicle; an autonomous driving control unit configured to execute an autonomous driving control including calculation of a requested deceleration of the industrial vehicle based on the map information, the position information, and the traveling information; and a braking force control unit configured to control the braking member such that a distribution of the regenerative braking force and the mechanical braking force is changeable based on the requested deceleration. In the braking control device, the braking force control unit is configured to: determine whether a first condition or a second condition is satisfied based on the map information and the position information, the first condition indicating that a first predetermined period of time has elapsed since the industrial vehicle started traveling downhill, the second condition indicating that the industrial vehicle is traveling downhill on a downhill slope having a predetermined gradient or more; and control the braking member in accordance with a first distribution when the first condition or the second condition is satisfied during autonomous driving of the industrial vehicle, the first distribution in which the mechanical braking force is large as compared with the mechanical braking force in a second distribution for a case where neither the first condition nor the second condition is satisfied.

[0008] In the braking control device for the industrial vehicle according to one aspect of the present invention, the braking force control unit controls the braking member. In the control of the braking member, the distribution of the regenerative braking force and the mechanical braking force is changeable based on the requested deceleration. The braking force control unit is configured to: determine whether the first condition indicating that the first predetermined period of time has elapsed since the industrial vehicle started traveling downhill or the second condition indicating that the industrial vehicle is traveling downhill on the downhill slope having a predetermined gradient or more is satisfied, based on the position information and the map information. By the determination of the first condition or the second condition as above, the industrial vehicle is determined to be traveling downhill even in the autonomous driving in which a traveling route is not

set in advance. When the first condition or the second condition is satisfied during the autonomous driving of the industrial vehicle, the braking member is controlled in accordance with the first distribution in which the mechanical braking force is large as compared with the mechanical braking force in the second distribution for a case where neither the first condition nor the second condition is satisfied during the autonomous driving of the industrial vehicle. As a result, a regenerative current is suppressed in the industrial vehicle traveling downhill. Thus, pre-limit of a charging amount is unnecessary, assuming that the industrial vehicle travels downhill, for example. Therefore, according to the braking control device for the industrial vehicle, even in traveling downhill with the battery being in the fully charged state, braking may be suitably performed without necessarily generating the traveling plan in advance in consideration of the influence of the downhill slope existing in the traveling route with the autonomous driving.

[0009] In one embodiment, the braking force control unit may be configured to: determine whether a release condition indicating that a second predetermined period of time has elapsed after satisfaction of the first condition or traveling downhill has ended after satisfaction of the second condition; and end the control of the braking member in accordance with the first distribution, when the release condition is satisfied during the control of the braking member in accordance with the first distribution. In this case, the control of the braking member in accordance with the first distribution may be ended based on a predetermined period of time after satisfaction of the first condition or the gradient after satisfaction of the second condition.

[0010] In one embodiment, the braking force control unit may determine whether the first condition or the second condition is satisfied based on a regenerative current of the traveling motor. In this case, whether the first condition or the second condition is satisfied may be determined by determination in which the industrial vehicle is traveling downhill when the regenerative current of the traveling motor becomes equal to or more than a predetermined current threshold value, for example.

Advantageous Effects of Invention

[0011] According to the present invention, braking may be suitably performed even when an industrial vehicle travels on a downhill slope existing in the traveling route with the autonomous driving when the battery is in a fully charged state without necessarily generating the traveling plan in advance in consideration of the influence of the downhill slope.

BRIEF DESCRIPTION OF DRAWINGS

[0012] FIG. 1 is a schematic configuration diagram of an industrial vehicle to which a braking control device for an industrial vehicle according to one embodiment is applied.

FIG. 2 is a block diagram illustrating a functional configuration of the braking control device for the industrial vehicle in FIG. 1.

FIG. 3 is a diagram illustrating an operation example of the braking control device for the industrial vehicle in FIG. 1.

FIG. 4 is a flowchart illustrating a processing example of the braking control device for the industrial vehicle in FIG. 1.

DESCRIPTION OF EMBODIMENTS

[0013] An embodiment of the present invention is described in detail below with reference to the drawings. In the drawings, the same or equivalent elements are denoted by the same reference characters and overlapping descriptions are omitted.

[0014] FIG. 1 is a schematic configuration diagram of an industrial vehicle to which a braking control device for an industrial vehicle according to one embodiment is applied. An industrial vehicle 1 illustrated in FIG. 1 is an electric

towing tractor, for example, and is used for towing a container loaded with cargo in an airport, a factory, a harbor, and the like.

[0015] The industrial vehicle 1 is configured to perform an autonomous driving control. The autonomous driving is a driving state in which a vehicle control causing the industrial vehicle 1 to autonomously travel in accordance with a conveyance command from an operation management system and the like, for example. The operation management system is a so-called control system that gives the conveyance command and monitors the operation, a vehicle state, and the like of the industrial vehicle 1. In the autonomous driving, an operator does not need to perform the driving operation, and the vehicle autonomously travels.

[0016] The autonomous driving herein is performed in a predetermined area including a runway, a take-off and landing zone, a taxiway, an apron, a control tower, a hangar, a cargo handling place, a charging place, and the like in an airport, for example. The industrial vehicle 1 can perform autonomous driving in which a traveling route is not set in advance or autonomous driving in which a traveling route is set in advance without considering an influence of a downhill slope existing in the traveling route, within a predetermined area.

[0017] [Configuration according to Traveling and Braking of Industrial Vehicle 1]

The industrial vehicle 1 includes a FL wheel 2 and a FR wheel 3 disposed in a front part of a vehicle body, and a RL wheel 4 and a RR wheel 5 disposed in a rear part of the vehicle body. The industrial vehicle 1 includes a left traveling motor 6 and a right traveling motor 7 serving as traveling motors. The left traveling motor 6 drives the RL wheel 4, and the right traveling motor 7 drives the RR wheel 5. The traveling motors also serve as a braking member 8 that generates a regenerative braking force.

[0018] The left traveling motor 6 and the right traveling motor 7 are AC motors that also function as electric generators. A left drive unit 6a that is a decelerator is interposed between the left traveling motor 6 and the RL wheel 4. A right drive

unit 7a that is a decelerator is interposed between the right traveling motor 7 and the RR wheel 5.

[0019] The left traveling motor 6 is electrically connected to a contactor 9 via a left motor driver 6b. The right traveling motor 7 is electrically connected to the contactor 9 via a right motor driver 7b. The left motor driver 6b and the right motor driver 7b each have an inverter, for example, and are electrically connected to a controller 10. In the left motor driver 6b and the right motor driver 7b, the controller 10 controls power running and regeneration of the left traveling motor 6 and the right traveling motor 7. The left motor driver 6b and the right motor driver 7b may detect regenerative current of the left traveling motor 6 and the right traveling motor 7, respectively.

[0020] The contactor 9 is electrically connected to a battery B. The contactor 9 is electrically connected to the controller 10. In the contactor 9, the controller 10 controls power supply from the battery B including emergency stop.

[0021] The battery B is a power supply source for the left traveling motor 6 and the right traveling motor 7. The battery B is a storage battery formed of a lead-acid battery, for example, and capable of storing therein regenerative electric power generated by regenerative braking of the left traveling motor 6 and the right traveling motor 7.

[0022] When the left traveling motor 6 is rotatably driven, a driving force of the left traveling motor 6 is transmitted to the RL wheel 4 via the left drive unit 6a to cause the RL wheel 4 to rotate. The left traveling motor 6 also functions as an electric generator. Specifically, at a time of the braking of the industrial vehicle 1, the left traveling motor 6 operates as the electric generator by the rotation of the RL wheel 4. That is, the regenerative braking of the left traveling motor 6 generates the regenerative electric power from the left traveling motor 6, and generates the regenerative braking force to brake the RL wheel 4.

[0023] When the right traveling motor 7 is rotatably driven, a driving force of the right traveling motor 7 is transmitted to the RR wheel 5 via the right drive unit 7a to cause the RR wheel 5 to rotate. The right traveling motor 7 also functions as an electric generator. Specifically, at a time of the braking of the industrial vehicle 1, the right traveling motor 7 operates as the electric generator by the rotation of the RR wheel 5. That is, the regenerative braking of the right traveling motor 7 generates the regenerative electric power from the right traveling motor 7, and generates the regenerative braking force to brake the RR wheel 5.

[0024] The industrial vehicle 1 includes a FL disc brake 8a, a FR disc brake 8b, a RL drum brake 8c, and a RR drum brake 8d serving as mechanical brakes included in the braking member 8. The FL disc brake 8a and the FR disc brake 8b are disposed in the front part of the vehicle body and mounted to the FL wheel 2 and the FR wheel 3 so as to brake the FL wheel 2 and the FR wheel 3, respectively. The RL drum brake 8c and the RR drum brake 8d are disposed in a rear part of the vehicle body and mounted to the RL wheel 4 and the RR wheel 5 so as to brake the RL wheel 4 and the RR wheel 5, respectively.

[0025] The industrial vehicle 1 includes a brake pedal 30, a master cylinder 31, and an ESC unit 32. When an operator drives the industrial vehicle 1 (at a time of manual driving), the operator steps on the brake pedal 30.

[0026] The master cylinder 31 generates hydraulic pressure in response to the operator stepping on the brake pedal 30. The master cylinder 31 is connected to the ESC unit 32 through a hydraulic circuit. The ESC unit 32 is a hydraulic control unit in which a processor, a motor, a pump, and a valve are integrated with each other, for example. The processor is an arithmetic unit such as a central processing unit (CPU). The processor controls a read only memory (ROM), a random access memory (RAM), and a communication interface in a supervising manner, for example.

[0027] The ESC unit 32 is electrically connected to the controller 10. A hydraulic sensor is built in the ESC unit 32, and hydraulic information detected by the hydraulic sensor is transmitted to the controller 10. The controller 10 controls the ESC unit 32 in response to a control signal from the controller 10 based on the hydraulic information, for example.

[0028] The ESC unit 32 is connected to the FL disc brake 8a and the FR disc brake 8b through a hydraulic circuit 33 for front-wheel braking. The ESC unit 32 is connected to the RL drum brake 8c and the RR drum brake 8d through a hydraulic circuit 34 for rear-wheel braking.

[0029] When the operator steps on the brake pedal 30, a piston disposed in a cylinder tube of the master cylinder 31 is pushed, so that hydraulic oil flows from the master cylinder 31 into the ESC unit 32. The hydraulic oil having flowed into the ESC unit 32 is supplied to independently each of the hydraulic circuit 33 and the hydraulic circuit 34. As a result, the hydraulic oil is supplied to the FL disc brake 8a and the FR disc brake 8b to cause the FL disc brake 8a and the FR disc brake 8b to operate, so that the FL wheel 2 and the FR wheel 3 are braked by a mechanical braking force. The hydraulic oil is supplied to the RL drum brake 8c and the RR drum brake 8d to cause the RL drum brake 8c and the RR drum brake 8d to operate, so that the RL wheel 4 and the RR wheel 5 are braked by a mechanical braking force, independently from the front-wheel braking.

[0030] The industrial vehicle 1 includes a left electromagnetic brake 6c and a right electromagnetic brake 7c mounted to the left traveling motor 6 and the right traveling motor 7 so as to brake the left traveling motor 6 and the right traveling motor 7, respectively. The left electromagnetic brake 6c and the right electromagnetic brake 7c are electrically connected to the controller 10 and used as parking brakes at a time of parking of the industrial vehicle 1.

[0031] [Configuration according to Autonomous Driving Control and Braking Control of Industrial Vehicle 1]

FIG. 2 is a block diagram illustrating a functional configuration of a braking control device for the industrial vehicle in FIG. 1. A braking control device 100 for the industrial vehicle includes the controller 10 that supervises the braking control and the autonomous driving control of the industrial vehicle 1. The controller 10 is an electronic control unit including a CPU, a ROM, a RAM, and the like. In the controller 10, for example, various functions are realized by loading a program recorded on the ROM onto the RAM and executing the program loaded on the RAM by the CPU. The controller 10 may detect a voltage of the battery B. The controller 10 may be formed of a plurality of electronic units.

[0032] The controller 10 is connected to a GNSS receiver 21, a peripheral situation sensor 22, a traveling information sensor 23, and a map database 24.

[0033] The GNSS receiver 21 measures a position of the industrial vehicle 1 (for example, a latitude and a longitude of the industrial vehicle 1) on a map by receiving signals from three or more GNSS satellites. The GNSS receiver 21 transmits the measured position information of the industrial vehicle 1 to the controller 10.

[0034] The peripheral situation sensor 22 is an in-vehicle detector that detects a situation around the vehicle. The peripheral situation sensor 22 includes a camera and a LiDAR (light detection and ranging). Imaging information of the camera is used for road surface pattern recognition and matching, for example. Obstacle information detected by the LiDAR is used for danger avoidance of the industrial vehicle 1, for example. The peripheral situation sensor 22 transmits information relating to a peripheral situation of the industrial vehicle 1 to the controller 10.

[0035] The traveling information sensor 23 is a detector that detects a traveling state of the industrial vehicle 1. The traveling information sensor 23 includes a vehicle speed sensor, an acceleration sensor, and a yaw rate sensor (gyroscope sensor). The vehicle speed sensor is a detector that detects a speed of the

industrial vehicle 1. Examples of the vehicle speed sensor include speed sensors that are respectively provided in the left traveling motor 6 and the right traveling motor 7 and detect a rotational speed of the left traveling motor 6, a rotational speed of the right traveling motor 7, and the like. The traveling information sensor 23 transmits the detected traveling information to the controller 10.

[0036] The map database 24 is a database that stores therein map information. The map database 24 is formed in a storage device (for example, a hard disk drive (HDD)) mounted on the industrial vehicle 1, for example. Examples of the map information include, as information in a predetermined area including a runway, a take-off and landing zone, a taxiway, an apron, a control tower, a hangar, a cargo handling place, a charging place, and the like in an airport, position information of a road, information of a road shape (a type of a curve and a straight line portion, a curvature of the curve, and a gradient of the road, for example), position information of an intersection and a crossroads, position information of a structure, and the like. The map information includes position information of a road surface pattern used for the position recognition of the industrial vehicle 1. The map database 24 may be provided in a server capable of communicating with the industrial vehicle 1.

[0037] Next, the functional configuration of the controller 10 will be described. The controller 10 includes a map information acquisition unit 11, a position information acquisition unit 12, a traveling information acquisition unit 13, an autonomous driving control unit 14, and a braking force control unit 15. Some of the functions of the controller 10 described below may be executed in a server capable of communicating with the vehicle.

[0038] The map information acquisition unit 11 acquires the map information stored in the map database 24. The map information acquisition unit 11 acquires at least the position information of the road surface pattern used for the position recognition of the industrial vehicle 1, and gradient information of the road.

[0039] The position information acquisition unit 12 acquires the position information of the industrial vehicle 1 based on a reception result of the GNSS receiver 21, a detection result of the peripheral situation sensor 22, and map information of the map database 24. The position information acquisition unit 12 acquires an own position of the industrial vehicle 1 based on the position information of the road surface pattern included in the map information and relative position information of the road surface pattern relative to the industrial vehicle 1 detected by the peripheral situation sensor 22. The position information acquisition unit 12 may estimate the own position of the industrial vehicle 1 with use of a simultaneous localization and mapping (SLAM) approach, for example.

[0040] The traveling information acquisition unit 13 acquires traveling information of the industrial vehicle 1 based on a detection result of the traveling information sensor 23. The traveling information acquisition unit 13 herein acquires the vehicle speed of the industrial vehicle 1 based on detection results of the speed sensors provided in the left traveling motor 6 and the right traveling motor 7, respectively. The traveling information acquisition unit 13 may acquire an orientation of the industrial vehicle 1 based on the detection result of the gyroscope sensor.

[0041] The autonomous driving control unit 14 executes the autonomous driving control including calculation of a requested deceleration of the industrial vehicle 1 based on the position information, the traveling information, and the map information. The autonomous driving control unit 14 generates a traveling plan along a target route based on the position information of the industrial vehicle 1 measured by the GNSS receiver 21, the map information of the map database 24, the peripheral situation (a position of an obstacle and the like) of the industrial vehicle 1 recognized from the detection result of the peripheral situation sensor 22, and the traveling state (the vehicle speed, the yaw rate, and the like) recognized from the detection result of the traveling information sensor 23. The target route

is set in accordance with the conveyance command from the operation management system and the like.

[0042] The autonomous driving control unit 14 executes the autonomous driving along the traveling plan. The traveling plan includes a target speed, a requested acceleration, and a requested deceleration, for example. The autonomous driving control unit 14 herein executes the autonomous driving control and the braking control such that the target speed, the requested acceleration, and the requested deceleration are realized by transmitting control signals to the left drive unit 6a, the right drive unit 7a, and the ESC unit 32.

[0043] As one example, the autonomous driving control unit 14 sets the target speed in accordance with the position of the industrial vehicle 1. For example, when the industrial vehicle 1 travels downhill, the autonomous driving control unit 14 sets the target speed to a predetermined constant speed (for example, 15 km/h), and calculates the deceleration of 0 as a requested deceleration such that the vehicle speed of the industrial vehicle 1 is maintained at the target speed. In this case, for example, when the downhill slope has a constant gradient, a required braking force is calculated as a substantially constant braking force. The required braking force means a braking force necessary for realizing the requested deceleration.

[0044] The braking force control unit 15 controls the braking member 8 such that a distribution of the regenerative braking force and the mechanical braking force is changeable based on the requested deceleration. The braking force control unit 15 changes the distribution of the regenerative braking force and the mechanical braking force based on the position information of the industrial vehicle 1 and the map information of the map database 24.

[0045] In the present embodiment, a change of the distribution of the regenerative braking force and the mechanical braking force means the change of the regenerative braking force along with the change of the mechanical braking force.

Specifically, the braking force control unit 15 calculates the regenerative braking force based on a change rate of the rotational speed of each of the left traveling motor 6 and the right traveling motor 7 detected by the speed sensor. The braking force control unit 15 calculates a target rotational speed at which a requested deceleration (a negative acceleration of the industrial vehicle 1) is achieved and calculates the regenerative braking force such that the change rate of the detected rotational speed reaches the target rotational speed (for example, the rotational speed decreases by a predetermined amount after an elapse of predetermined seconds). Thus, when the mechanical braking force coexists, the target rotational speed corresponding to the deceleration from which the amount of the deceleration caused by the mechanical braking force has been subtracted is calculated. Therefore, the distribution of the regenerative braking force becomes smaller as the distribution of the mechanical braking force becomes greater, and the distribution of the regenerative braking force becomes greater as the distribution of the mechanical braking force becomes smaller.

[0046] The braking force control unit 15 determines whether a first condition or a second condition is satisfied based on the position information of the industrial vehicle 1 and the gradient information of the road on which the industrial vehicle 1 is traveling, for example. The first condition indicates that a first predetermined period of time has elapsed since the industrial vehicle 1 started traveling downhill. The second condition indicates that the industrial vehicle 1 is traveling downhill on a downhill slope having a predetermined gradient or more. The first condition and the second condition are conditions for determining whether the distribution of the regenerative braking force and the mechanical braking force is changed. The first condition and the second condition are determined in real time based on the gradient information of the road on which the industrial vehicle 1 is traveling, and hence may be considered to be conditions for suppressing the regenerative braking without necessarily generating the traveling plan in advance in consideration of the influence of the downhill slope existing in the traveling route with the autonomous driving.

[0047] The first predetermined period of time is equivalent to a period of time for checking that traveling downhill is continuing since the industrial vehicle 1 started traveling downhill. The first period of time may be a constant value about several seconds, for example, or may become shorter as a downward gradient becomes greater.

[0048] The predetermined gradient has a gradient value equivalent to a case where a regenerative current becomes equal to or more than a certain extent while the industrial vehicle 1 is traveling downhill. The predetermined gradient is compared with the gradient information acquired based on the map database 24. The predetermined gradient may have a constant value as a magnitude of a downward gradient equivalent to a predetermined regenerative current value or may have a gradient value that becomes smaller as the battery B becomes closer to a fully charged state, for example.

[0049] The braking force control unit 15 may determine whether the first condition or the second condition is satisfied, based on the regenerative current of the left traveling motor 6 and the right traveling motor 7. Whether the regenerative current has become equal to or more than a certain extent while the industrial vehicle 1 is traveling downhill may be determined based on the regenerative current (a regenerative current generated by regenerative braking in accordance with a second distribution R2 which will be described later) detected in the left motor driver 6b and the right motor driver 7b instead of an approach based on the comparison of the predetermined gradient with the gradient information.

[0050] The braking force control unit 15 controls the braking member 8 such that the distribution of the regenerative braking force and the mechanical braking force is set to a second distribution when neither the first condition nor the second condition is satisfied including a case where the industrial vehicle 1 is traveling on a flat ground, for example. The second distribution is a distribution of a normal braking force used while the industrial vehicle 1 is traveling on the flat ground or on the downhill slope having a gradient less than the predetermined gradient, for

example. In the second distribution, the mechanical braking force may be set to be smaller than the regenerative braking force, for example (see the reference sign R2 in FIG. 3(a)).

5 [0051] FIG. 3 is a diagram illustrating an operation example of the braking control device for the industrial vehicle in FIG. 1. As illustrated in FIG. 3, for example, in a case where the industrial vehicle 1 is traveling on the flat ground, neither the first condition nor the second condition is satisfied during a period from time t_0 to time t_1 . In this case, the braking force control unit 15 controls the braking member 8
10 in accordance with the second distribution R2. In the example of FIG. 3, a required braking force B_{req} is set to be constant, assuming that the gradient of the downhill slope is constant and the target vehicle speed is constant. However, the required braking force may be temporally changed.

15 [0052] The braking force control unit 15 controls the braking member 8 in accordance with a first distribution R1 in which the mechanical braking force is large as compared with that in the second distribution R2, when the first condition or the second condition is satisfied during the autonomous driving of the industrial vehicle 1, for example. The first distribution R1 has the distribution of a braking
20 force used while the industrial vehicle 1 is traveling downhill on the downhill slope in which the regenerative braking is to be suppressed. For example, in the first distribution R1, the mechanical braking force may be greater than the regenerative braking force or only the mechanical braking force may be used without the regenerative braking force (see the reference sign R1 in FIG. 3 (a)).

25 [0053] In the example of FIG. 3, the braking force control unit 15 determines that the first condition or the second condition is satisfied at the time t_1 . Battery voltage V_1 at the time t_1 is equal to or less than battery voltage V_L in the fully charged state. That is, the first condition or the second condition may be set such
30 that the braking force control unit 15 determines that the first condition or the second condition are satisfied before the battery voltage exceeds the battery voltage V_L . The battery voltage V_L in the fully charged state is equivalent to

battery voltage having an upper limit beyond which the battery B deteriorates due to the overcharged state if the battery B is charged further. Thus, the braking member 8 is controlled in accordance with the first distribution R1, which suppresses a case where the voltage of the battery B reaches the battery voltage VL and avoids a situation where the voltage of the battery B reaches the battery voltage VL during the regenerative braking and the regenerative braking is thus suspended for the protection of the battery B, for example.

[0054] The braking force control unit 15 determines whether a release condition is satisfied. The release condition indicates that a second predetermined period of time has elapsed after satisfaction of the first condition or traveling downhill has ended after satisfaction of the second condition. When the release condition is satisfied during the control of the braking member 8 in accordance with the first distribution R1, the braking force control unit 15 ends the control of the braking member 8 in accordance with the first distribution R1. The release condition is a condition for determining whether the distribution of the mechanical braking force increased so as to suppress the regenerative braking force returns to the previous distribution.

[0055] The second predetermined period of time is equivalent to an estimated period of time by which traveling downhill is estimated to be ended because a certain period of time has elapsed since the industrial vehicle 1 started traveling downhill. The second period of time may be greater than the first period of time and may have a constant value of about 10 seconds, for example.

[0056] The expression of "traveling downhill has ended after satisfaction of the second condition" means that the gradient information after satisfaction of the second condition becomes less than the predetermined gradient based on the gradient information acquired based on the map database 24, for example. The regenerative current is suppressed in accordance with the first distribution R1 also when the second condition is determined based on the regenerative current detected in the left motor driver 6b and the right motor driver 7b instead of an

approach based on the comparison of the predetermined gradient with the gradient information. Therefore, a state where traveling downhill has ended may be determined using an approach based on the gradient information acquired based on the map database 24.

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[0057] In the example of FIG. 3, the braking force control unit 15 determines that the release condition is satisfied at time t3. The battery voltage at the time t3 corresponds to battery voltage V2 smaller than the battery voltage V1. The braking force control unit 15 determines that the release condition is satisfied at
10 the time t3, ends the control of the braking member 8 in accordance with the first distribution R1, and changes to the control of the braking member 8 in accordance with the second distribution R1, for example.

[0058] When the braking force control unit 15 changes the distribution of the
15 regenerative braking force and the mechanical braking force, the braking force control unit 15 may consecutively increase the distribution of the mechanical braking force in the distribution R2 which is applied before the distribution change to that in the distribution R1 which is applied after the distribution change, as in a period from the time t1 to time t2 of FIG. 3. Similarly, the braking force control
20 unit 15 may consecutively decrease the distribution of the mechanical braking force in the distribution R1 which is applied before the distribution change to that in the distribution R2 which is applied after the distribution change, as in a period from the time t3 to time t4 of FIG. 3. As a result, the regenerative braking force of the braking member 8 easily follows the change of the mechanical braking force.
25 This can stabilize the braking force generated in the entire braking member 8 as compared with a case where the distribution is rapidly changed.

[0059] [One Example of Arithmetic Processing by Controller 10]

Next, one example of arithmetic processing by the controller 10 will be
30 described. FIG. 4 is a flowchart illustrating a processing example of the braking control device for the industrial vehicle in FIG. 1. The processing illustrated in

FIG. 4 is executed during the autonomous driving of the industrial vehicle 1, for example.

[0060] As illustrated in FIG. 4, in Step S01, the controller 10 instructs the position information acquisition unit 12 to acquire the position information of the industrial vehicle 1. The position information acquisition unit 12 acquires the position information of the industrial vehicle 1 based on the reception result of the GNSS receiver 21, the detection result of the peripheral situation sensor 22, and the map information of the map database 24, for example.

[0061] In Step S02, the controller 10 instructs the traveling information acquisition unit 13 to acquire the traveling information of the industrial vehicle 1. The traveling information acquisition unit 13 acquires the traveling information of the industrial vehicle 1 based on the detection result of the traveling information sensor 23, for example.

[0062] In Step S03, the controller 10 instructs the braking force control unit 15 to acquire the gradient information of the road on which the industrial vehicle 1 travels. The braking force control unit 15 acquires the gradient information of the road on which the industrial vehicle 1 travels, based on the position information acquired by the position information acquisition unit 12 and the gradient information included in the map information of the map database 24, for example. The braking force control unit 15 may acquire the gradient information of the road on which the industrial vehicle 1 travels, based on the regenerative current (the regenerative current generated by the regenerative braking in accordance with the second distribution R2) of the left traveling motor 6 and the right traveling motor 7. The acquired gradient information is used for the determination of whether the first condition or the second condition is satisfied.

[0063] In Step S04, the controller 10 instructs the autonomous driving control unit 14 to acquire the traveling plan of the industrial vehicle 1. The autonomous driving control unit 14 acquires the traveling plan of the industrial vehicle 1 based

on the position information acquired by the position information acquisition unit 12 and the traveling information acquired by the traveling information acquisition unit 13, for example. The autonomous driving control unit 14 may acquire a traveling plan generated as the conveyance command by the operation management system capable of communicating with the industrial vehicle 1.

[0064] In Step S05, the controller 10 instructs the autonomous driving control unit 14 to acquire the requested deceleration of the industrial vehicle 1. The autonomous driving control unit 14 acquires the requested deceleration of the industrial vehicle 1 based on the traveling information acquired by the traveling information acquisition unit 13 and the traveling plan acquired by the autonomous driving control unit 14, for example.

[0065] In Step S06, the controller 10 instructs the braking force control unit 15 to determine whether the first condition is satisfied. The braking force control unit 15 determines whether the first condition indicating that the first predetermined period of time has elapsed since the industrial vehicle 1 started traveling downhill is satisfied, based on the position information and the map information, for example.

[0066] When the braking force control unit 15 determines that the first condition is not satisfied in Step S06, the controller 10 instructs the braking force control unit 15 to determine whether the second condition is satisfied in Step S07. The braking force control unit 15 determines whether the second condition indicating that the industrial vehicle 1 is traveling downhill on a downhill slope having a predetermined gradient or more is satisfied, based on the position information and the map information, for example.

[0067] When the braking force control unit 15 determines that the second condition is not satisfied in Step S07, the controller 10 instructs the braking force control unit 15 to control the braking member 8 in accordance with the second distribution in Step S08. The braking force control unit 15 controls the braking

member 8 in accordance with the second distribution, for example. Then, the controller 10 ends the processing of FIG. 4.

[0068] On the other hand, when the braking force control unit 15 determines that the first condition is satisfied in Step S06 or the braking force control unit 15 determines that the second condition is satisfied in Step S07, the controller 10 instructs the braking force control unit 15 to determine whether the release condition is unsatisfied in Step S09. The braking force control unit 15 determines whether the release condition indicating that the second predetermined period of time has elapsed after satisfaction of the first condition or traveling downhill has ended after satisfaction of the second condition is satisfied, for example.

[0069] When the braking force control unit 15 determines that the release condition is not unsatisfied (the release condition is satisfied) in Step S09, the controller 10 performs the processing of Step S08. For example, when the release condition is satisfied during the control of the braking member 8 in accordance with the first distribution, the braking force control unit 15 ends the control of the braking member 8 in accordance with the first distribution and controls the braking member 8 in accordance with the second distribution.

[0070] When the braking force control unit 15 determines that the release condition is unsatisfied (the release condition is not satisfied) in Step S09, the controller 10 performs the processing of Step S10. The braking force control unit 15 controls the braking member 8 in accordance with the first distribution in which the mechanical braking force is large as compared with the mechanical braking force in the second distribution for a case where neither the first condition nor the second condition is satisfied, for example. Then, the controller 10 ends the processing of FIG. 4.

[0071] [Operations and Effects]

As described above, in the braking control device 100 for the industrial vehicle according to the present embodiment, the braking force control unit 15

controls the braking member 8. In the control of the braking member 8, the distribution of the regenerative braking force and the mechanical braking force is changeable based on the requested deceleration. The braking force control unit 15 determines whether the first condition indicating that the first predetermined period of time has elapsed since the industrial vehicle 1 started traveling downhill or the second condition indicating that the industrial vehicle 1 is traveling downhill on the downhill slope having a predetermined gradient or more is satisfied, based on the position information and the map information. By the determination of the first condition or the second condition as above, the industrial vehicle 1 is determined to be traveling downhill even in the autonomous driving in which the traveling route is not set in advance. When the first condition or the second condition is satisfied during the autonomous driving of the industrial vehicle 1, the braking member 8 is controlled in accordance with the first distribution in which the mechanical braking force is large as compared with the mechanical braking force in the second distribution for a case where neither the first condition nor the second condition is satisfied during the autonomous driving of the industrial vehicle 1. This suppresses the regenerative current in the industrial vehicle 1 traveling downhill. As a result, pre-limit of the charging amount (a state of charge, SOC) is unnecessary, assuming that the industrial vehicle 1 is to travel on the downhill slope, for example. Thus, according to the braking control device 100 for the industrial vehicle, even in traveling downhill with the battery being in the fully charged state, braking may be suitably performed without necessarily generating the traveling plan in advance in consideration of the influence of the downhill slope.

[0072] For example, a situation may be suppressed in which the regenerative braking becomes unavailable and the braking force becomes insufficient (so-called regeneration loss) because the battery B reaches the fully charged state during deceleration mainly using the regenerative braking force. Moreover, the industrial vehicle 1 needs to have a wide range of possible values of the required braking force depending on the weight of a towed or handled cargo even on a downhill slope having an equivalent downward gradient. However, according to the braking control device 100 for the industrial vehicle, the braking member 8 is

controlled so as to increase the distribution of the mechanical braking force using the required braking force as the entire braking force. Thus, the braking may be suitably performed depending on the weight of the cargo.

5 [0073] In the braking control device 100 for the industrial vehicle, the braking force control unit 15 determines whether the release condition indicating that the second predetermined period of time has elapsed after satisfaction of the first condition or traveling downhill has ended after satisfaction of the second condition is satisfied. When the release condition is satisfied during the control of the
10 braking member in accordance with the first distribution, the braking force control unit 15 ends the control of the braking member 8 in accordance with the first distribution. As a result, the control of the braking member 8 in accordance with the first distribution may be ended based on a predetermined period of time after satisfaction of the first condition or the gradient after satisfaction of the second
15 condition.

[0074] In the braking control device 100 for the industrial vehicle, the braking force control unit 15 determines whether the first condition or the second condition is satisfied, based on the regenerative current of the left traveling motor 6 and the
20 right traveling motor 7. As a result, whether the first condition or the second condition is satisfied may be determined by determination in which the industrial vehicle 1 is traveling downhill when the regenerative current of the left traveling motor 6 and the right traveling motor 7 becomes equal to or more than a predetermined current threshold value, for example.

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[0075] [Modified Example]

An embodiment according to the present invention has been described above, but the present invention is not limited to the above-described embodiment.

30 [0076] In the above-described embodiment, although an electric towing tractor as in FIG. 1 is exemplified as the industrial vehicle 1, the industrial vehicle 1 is not limited to the electric towing tractor and may be an electric forklift or a hybrid

industrial vehicle, for example. In short, the industrial vehicle only needs to be an industrial vehicle in which the battery B is chargeable by regenerative braking, and needs to have a braking member that is formed of a traveling motor generating the regenerative braking force and a mechanical brake generating the mechanical
5 braking force, and to change the distribution of the regenerative braking force and the mechanical braking force based on a requested deceleration.

[0077] A configuration using the ESC unit 32 is exemplified as a system of the mechanical brake that generates the mechanical braking force, but other hydraulic
10 control devices may be used. The mechanical brake is not limited to a disc brake and a drum brake using hydraulic pressure, and the braking force of the left electromagnetic brake 6c and the right electromagnetic brake 7c may be used as the mechanical braking force.

[0078] The configuration for the autonomous driving of the industrial vehicle 1 is not limited to the example of the above-described embodiment. For example, the LiDAR is used in the peripheral situation sensor 22, but may be substituted by another sensor. The gradient information is included in the map information of the map database 24, but the gradient information may be omitted from the map
20 database 24 when the regenerative current is used for the determination of the first condition and the second condition.

[0079] In the above-described embodiment, the braking force control unit 15 sets the distribution of the regenerative braking force and the mechanical braking force
25 to one of the two stages, the first distribution R1 and the second distribution R2, as illustrated in FIG. 3. However, the stages may be three stages or more. In short, when the first condition or the second condition is satisfied, the regenerative braking force only needs to be suppressed as compared with a case where neither the first condition nor the second condition is satisfied.

[0080] At least some of the embodiment and various modified examples described above may be arbitrarily combined with each other.

Reference Signs List

	[0081]	1 ... Industrial vehicle
5		6 ... Left traveling motor (traveling motor)
		7 ... Right traveling motor (traveling motor)
		8 ... Braking member
		8a ... FL disc brake (mechanical brake)
		8b ... FR disc brake (mechanical brake)
10		8c ... RL drum brake (mechanical brake)
		8d ... RR drum brake (mechanical brake)
		10 ... Controller
		11 ... Map information acquisition unit
		12 ... Position information acquisition unit
15		13 ... Traveling information acquisition unit
		14 ... Autonomous driving control unit
		15...Braking force control unit
		100 ... Braking control device for industrial vehicle
		R2 ... Second distribution
20		R1 ... First distribution

CLAIMS

[Claim 1]

A braking control device for an industrial vehicle, the industrial vehicle including a braking member that is formed of a traveling motor generating a regenerative braking force used to charge a battery and a mechanical brake generating a mechanical braking force, the braking control device comprising:

a map information acquisition unit configured to acquire map information;

a position information acquisition unit configured to acquire position information of the industrial vehicle;

a traveling information acquisition unit configured to acquire traveling information of the industrial vehicle;

an autonomous driving control unit configured to execute an autonomous driving control including calculation of a requested deceleration of the industrial vehicle based on the map information, the position information, and the traveling information; and

a braking force control unit configured to control the braking member such that a distribution of the regenerative braking force and the mechanical braking force is changeable based on the requested deceleration, wherein

the braking force control unit is configured to:

determine whether a first condition or a second condition is satisfied based on the map information and the position information, the first condition indicating that a first predetermined period of time has elapsed since the industrial vehicle started traveling downhill, the second condition indicating that the industrial vehicle is traveling downhill on a downhill slope having a predetermined gradient or more; and

control the braking member in accordance with a first distribution when the first condition or the second condition is satisfied during autonomous driving of the industrial vehicle, the first distribution in which the mechanical braking force is large as compared with the mechanical braking force in a second distribution for a case where neither the first condition nor the second condition is satisfied.

[Claim 2]

The braking control device for the industrial vehicle according to claim 1, wherein

5 the braking force control unit is configured to:

determine whether a release condition is satisfied, the release condition indicating that a second predetermined period of time has elapsed after satisfaction of the first condition or traveling downhill has ended after satisfaction of the second condition; and

10 end the control of the braking member in accordance with the first distribution when the release condition is satisfied during the control of the braking member in accordance with the first distribution.

[Claim 3]

15 The braking control device for the industrial vehicle according to claim 1 or 2, wherein

the braking force control unit is configured to determine whether the first condition or the second condition is satisfied based on a regenerative current of the traveling motor.

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